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(54) **SEAFLOOR PIPELINE REMOVAL SYSTEM AND METHOD**

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E02F 3/92	(2006.01)
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F16L 1/16	(2006.01)
F16L 1/20	(2006.01)

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(58) **Field of Classification Search**

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See application file for complete search history.

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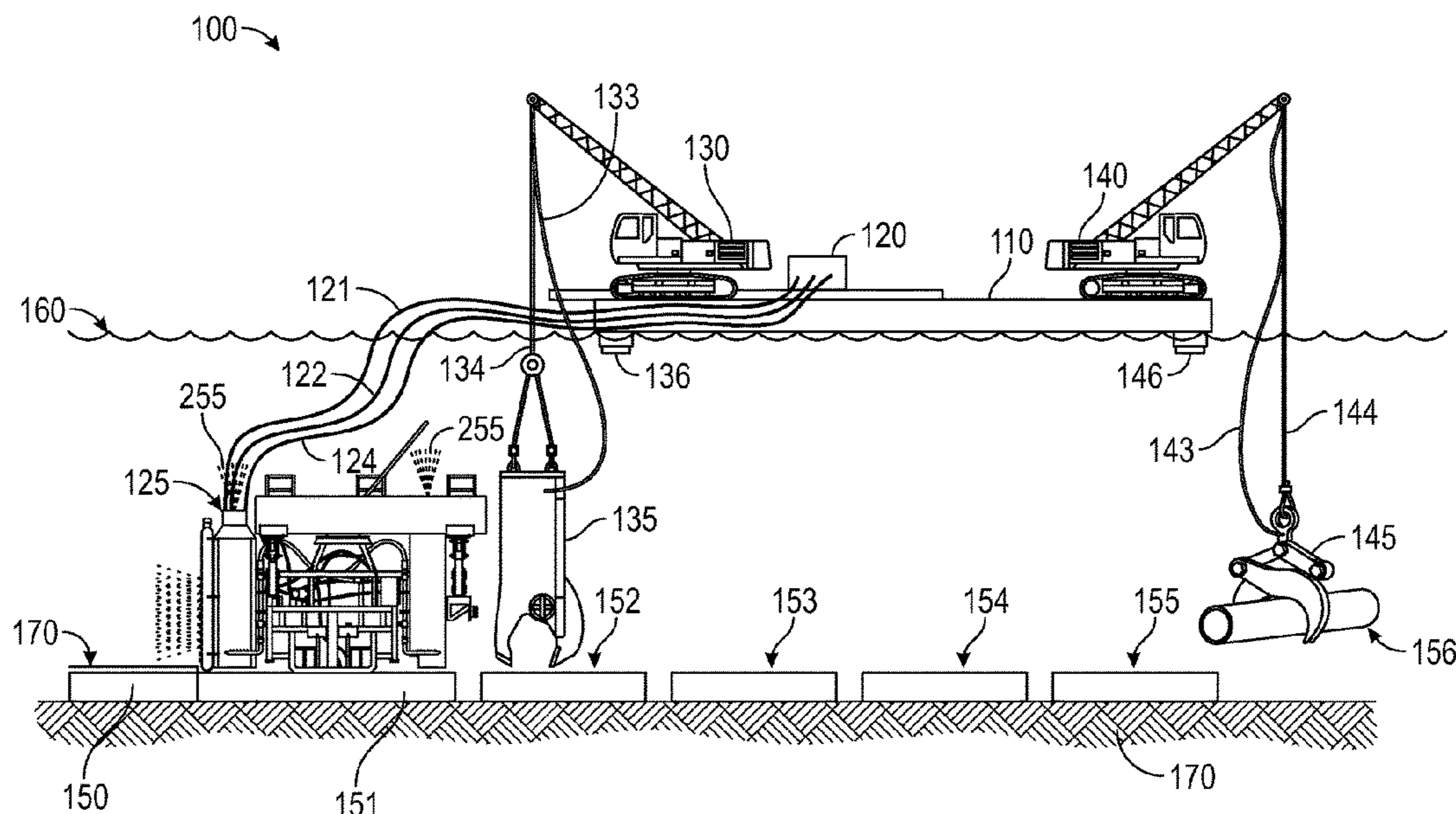
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(57) **ABSTRACT**

The present invention relates to a system and method for uncovering and removing pipeline from the seafloor using a subsea trenching system using pressurized water to uncover pipe, a subsea shear carried by a barge to cut lengths of the pipeline, and a grapple carried by a barge to lift cut lengths of pipeline for placement on a pipe haul and recovery barge.

3 Claims, 12 Drawing Sheets



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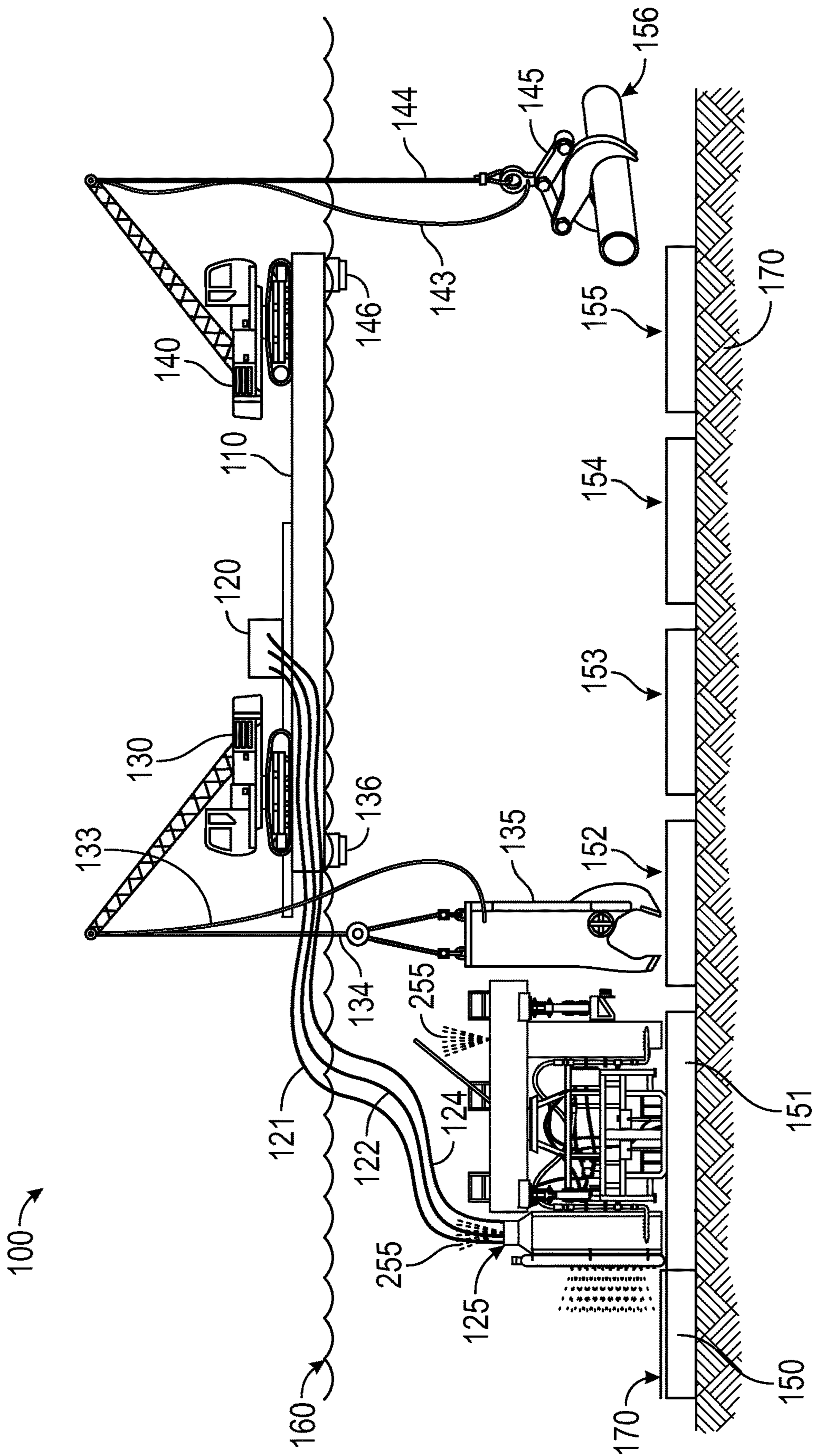


FIG. 1

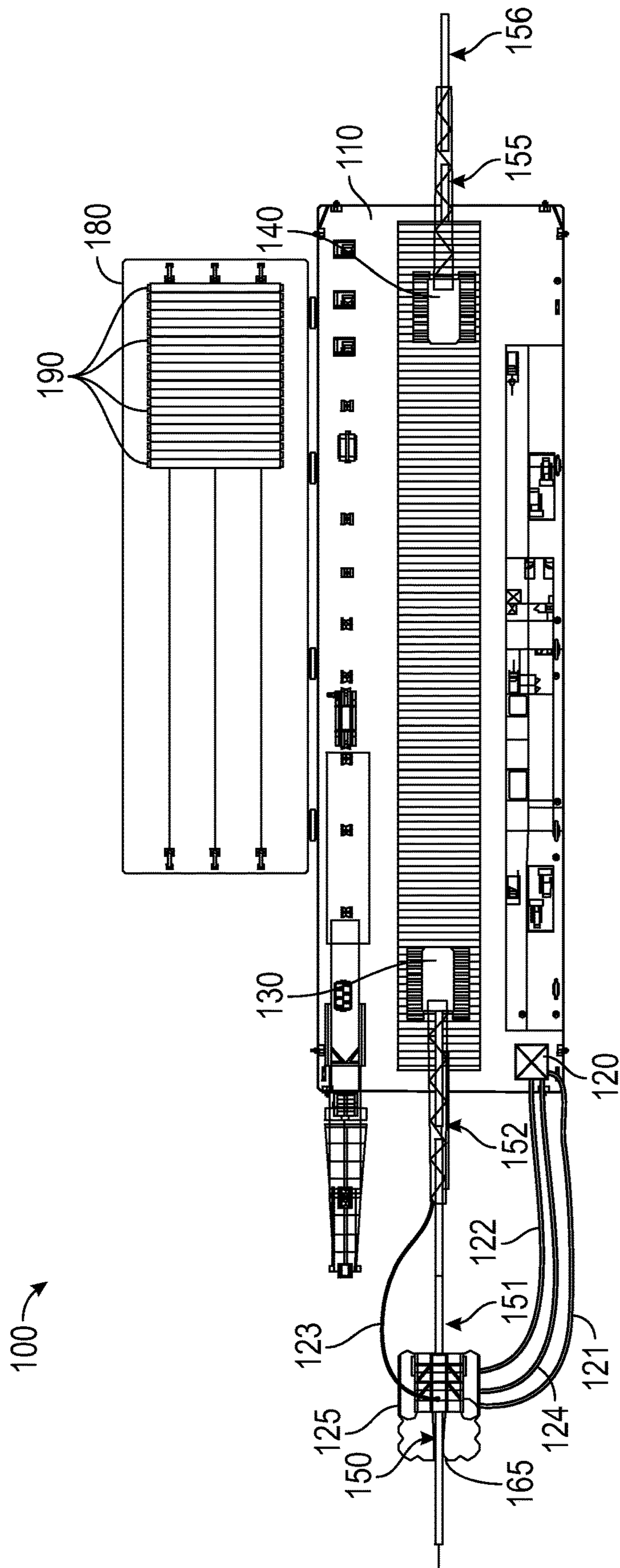


FIG. 2

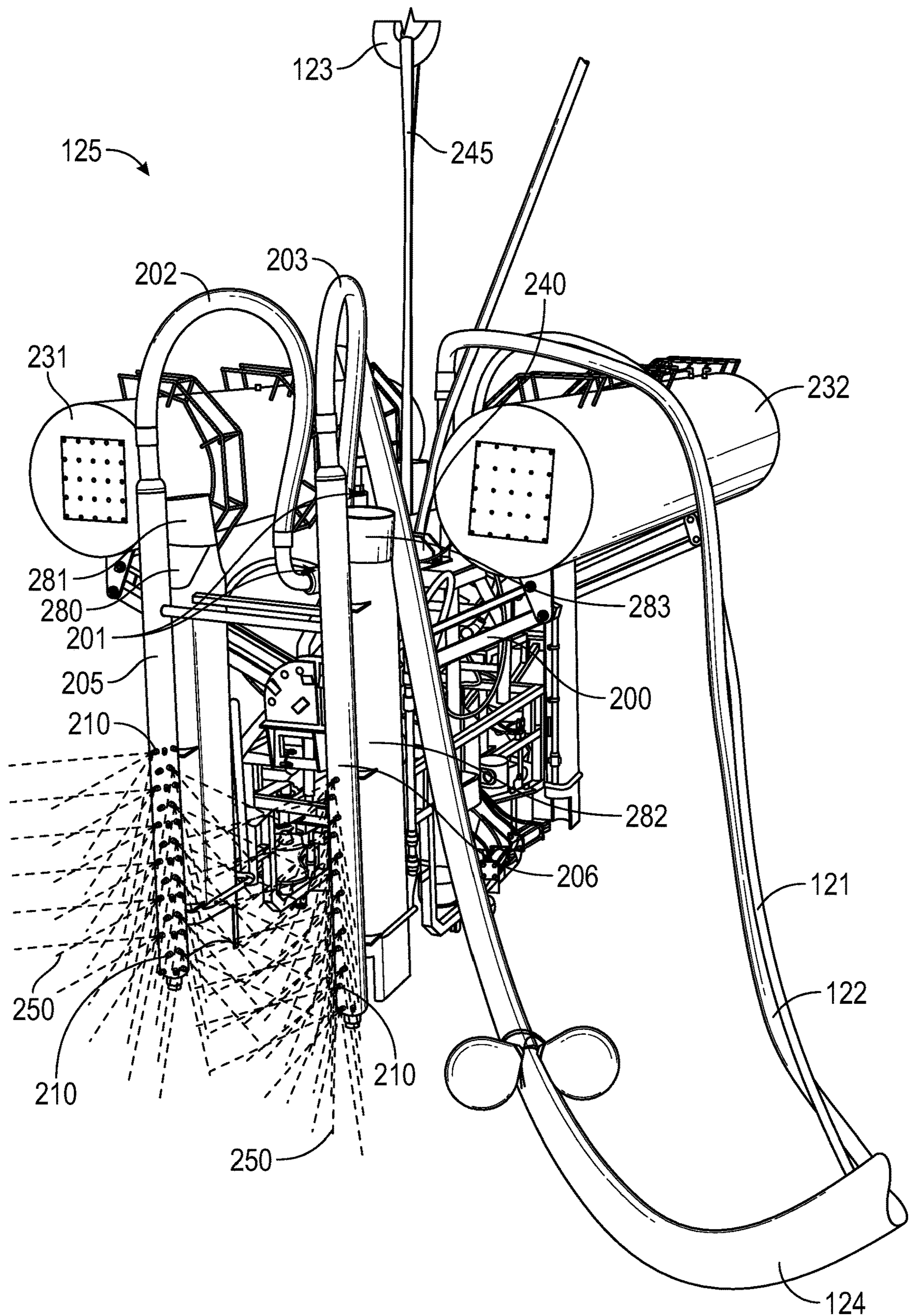


FIG. 3A

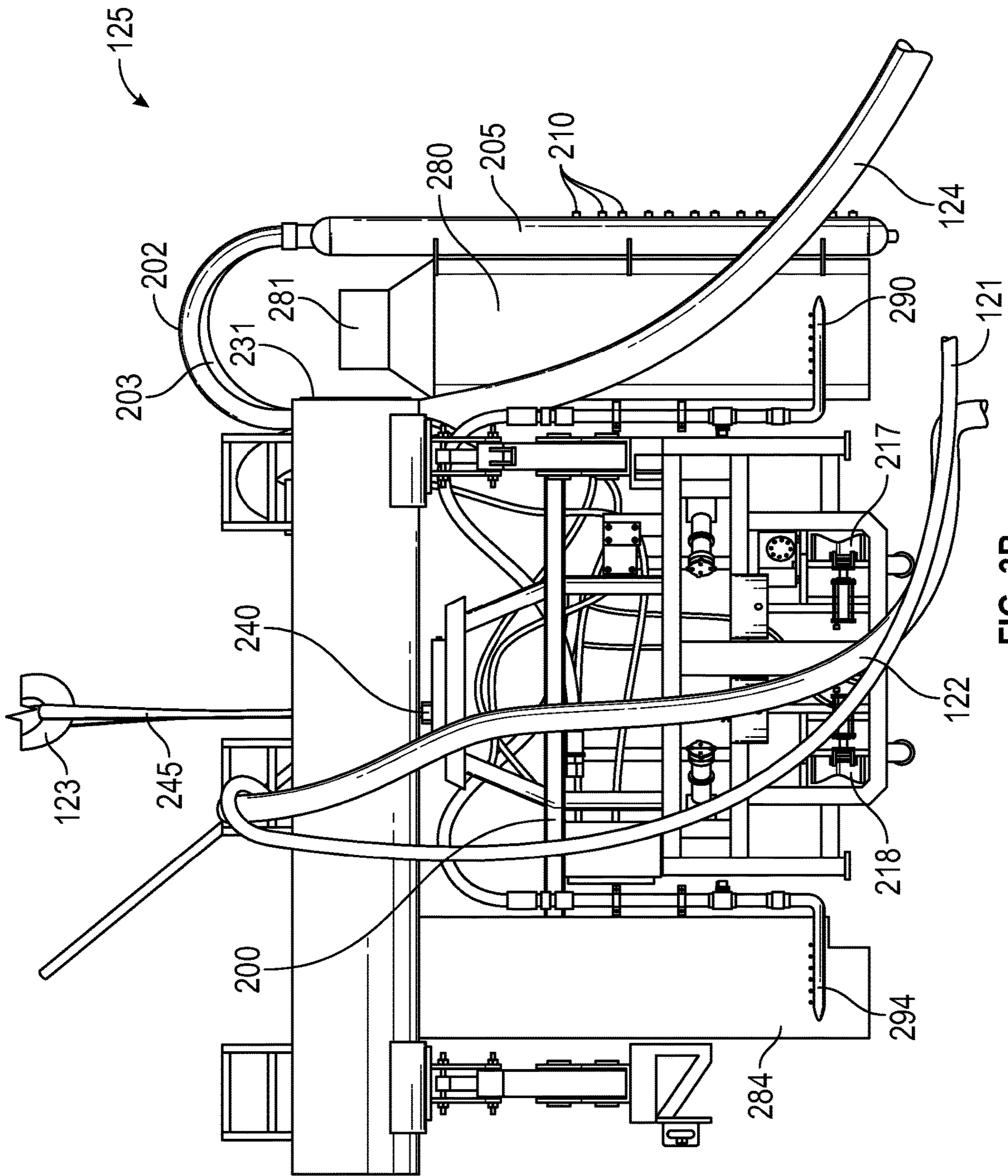


FIG. 3B

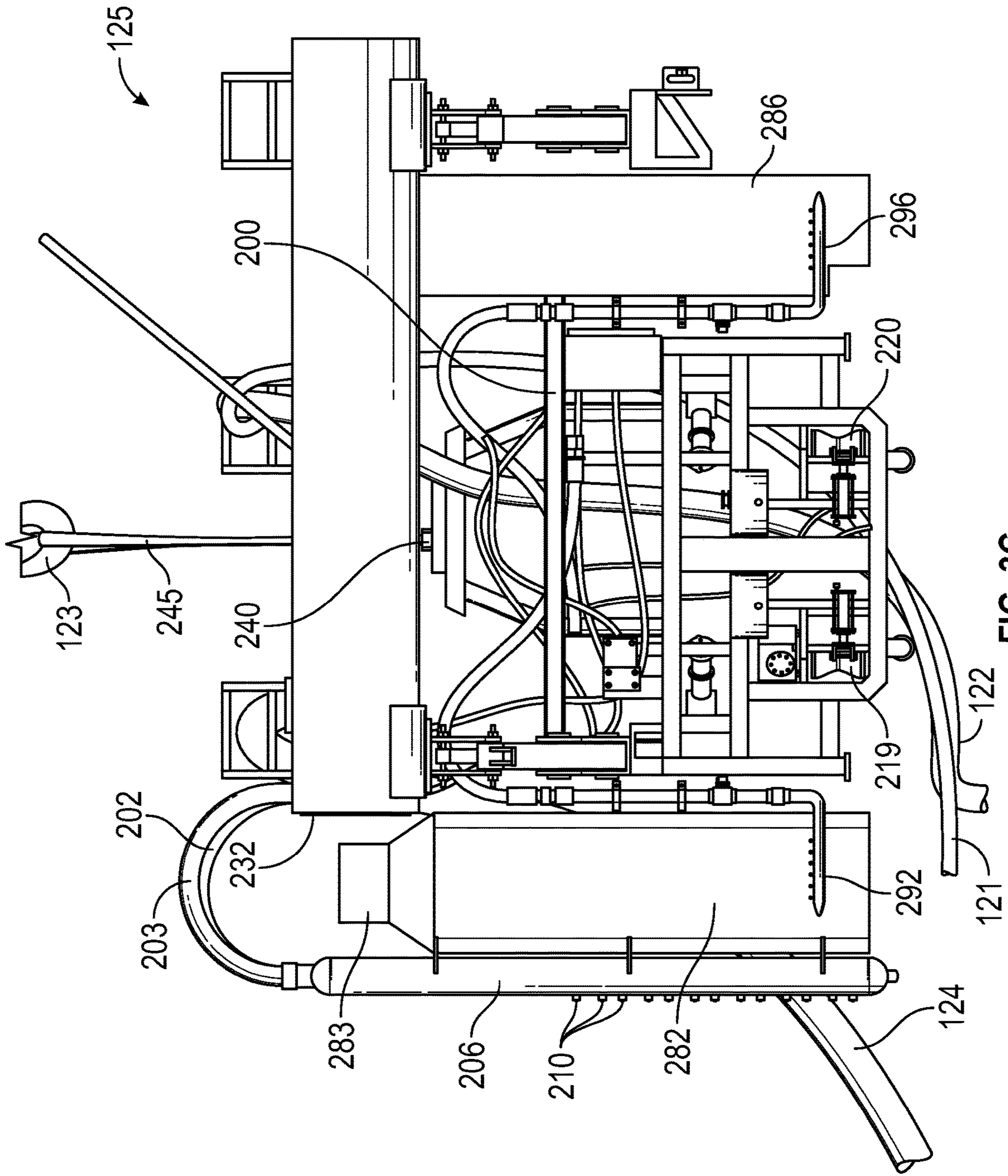


FIG. 3C

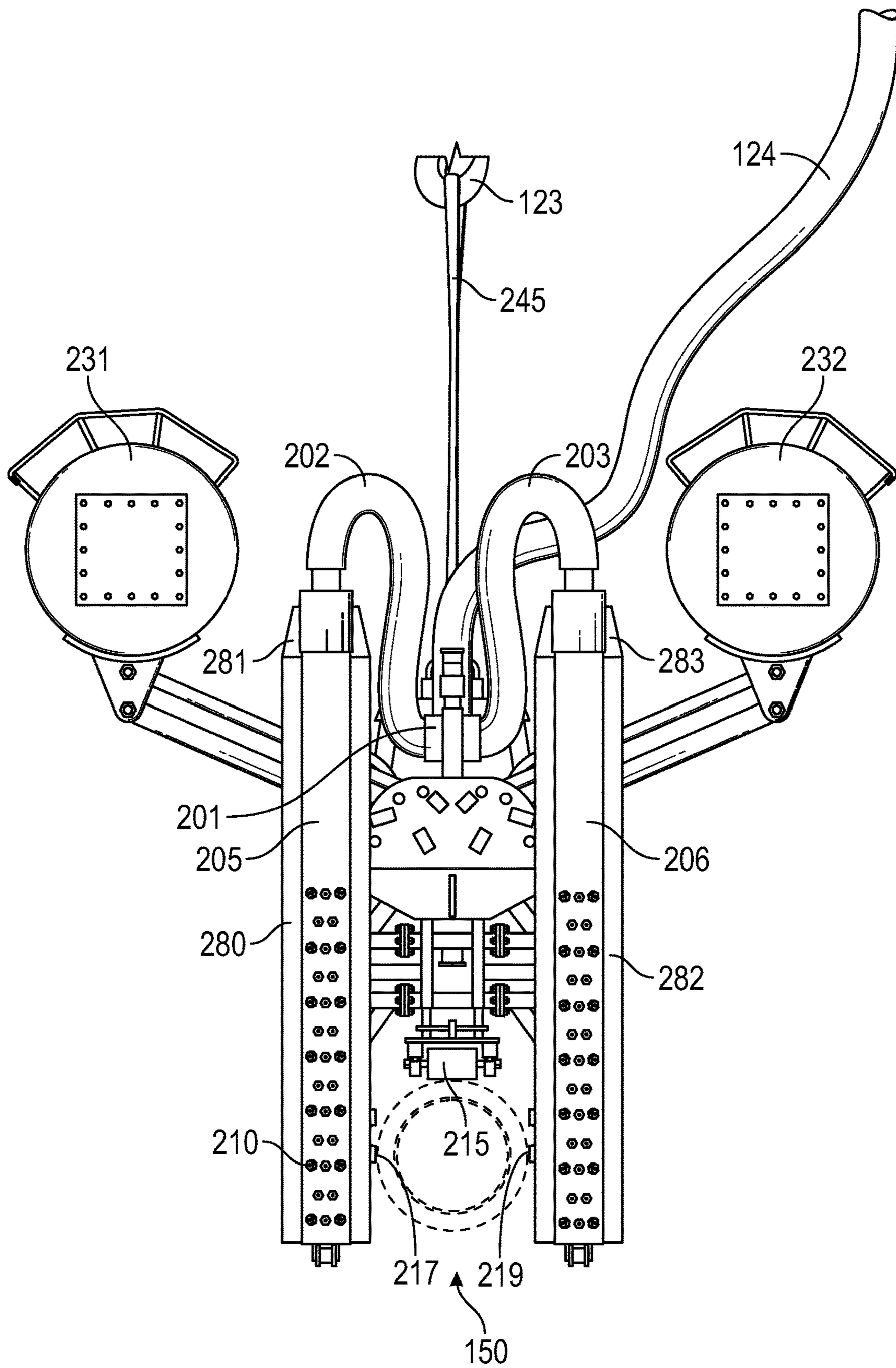


FIG. 3D

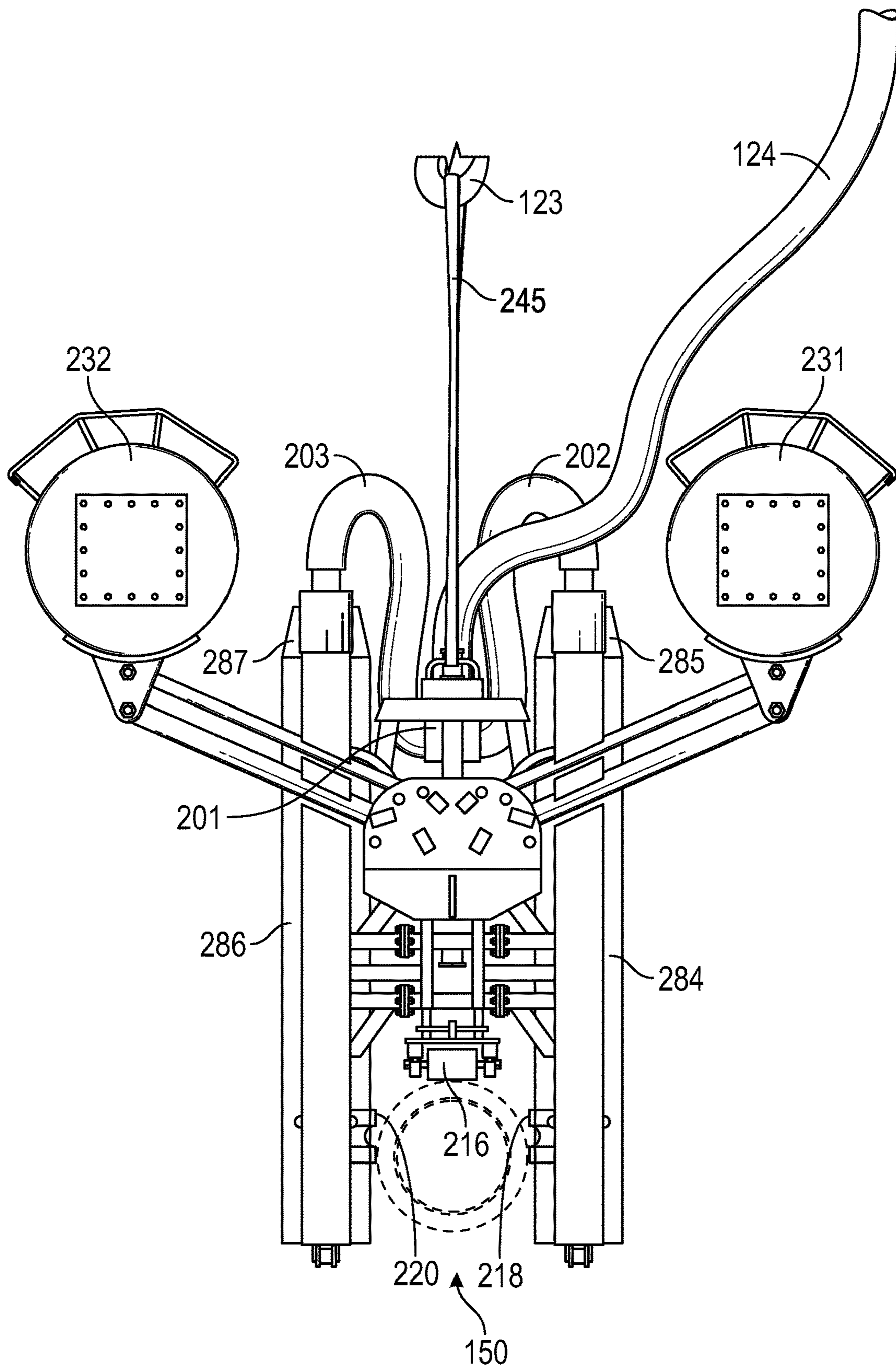


FIG. 3E

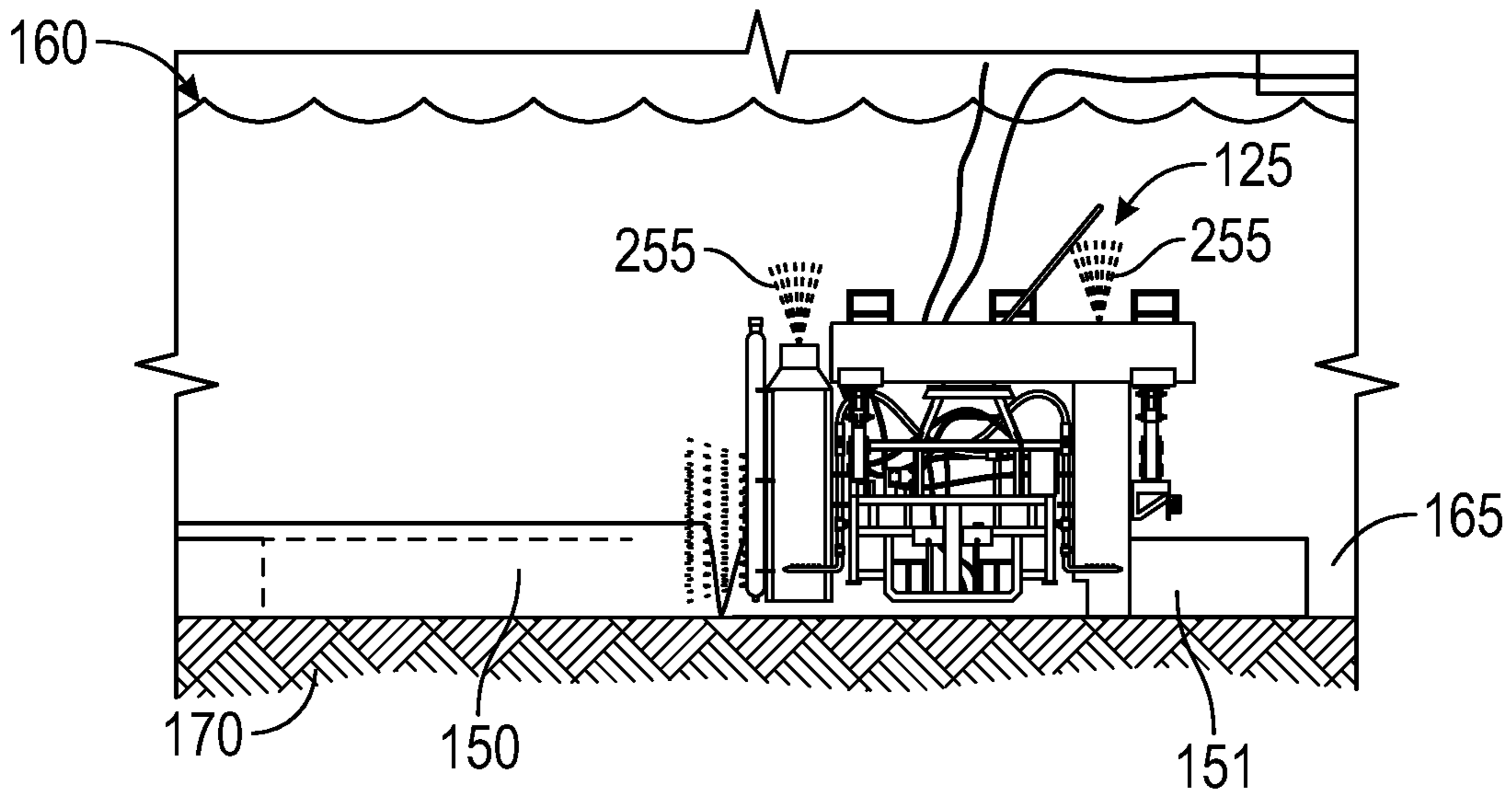


FIG. 3F

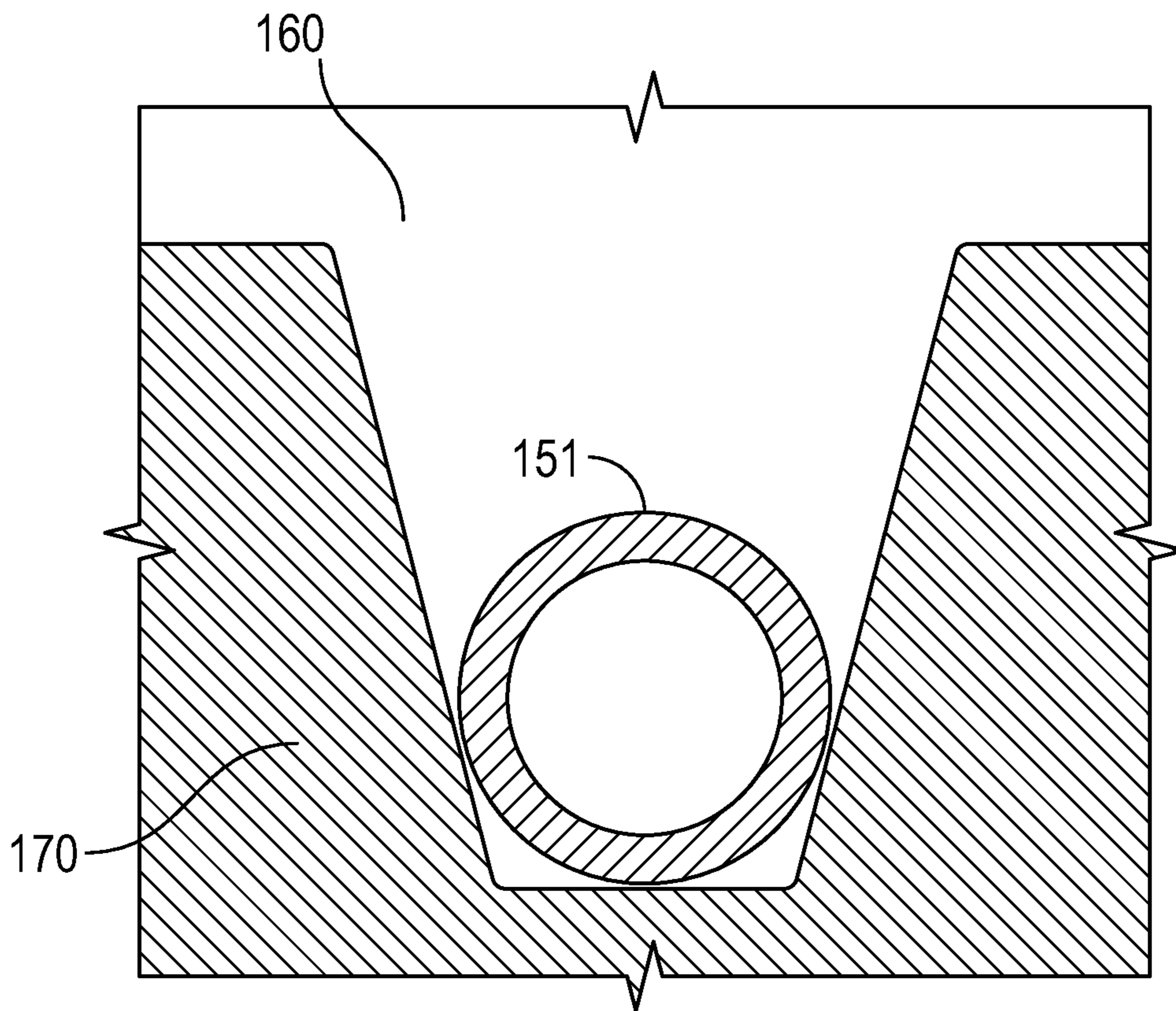


FIG. 3G

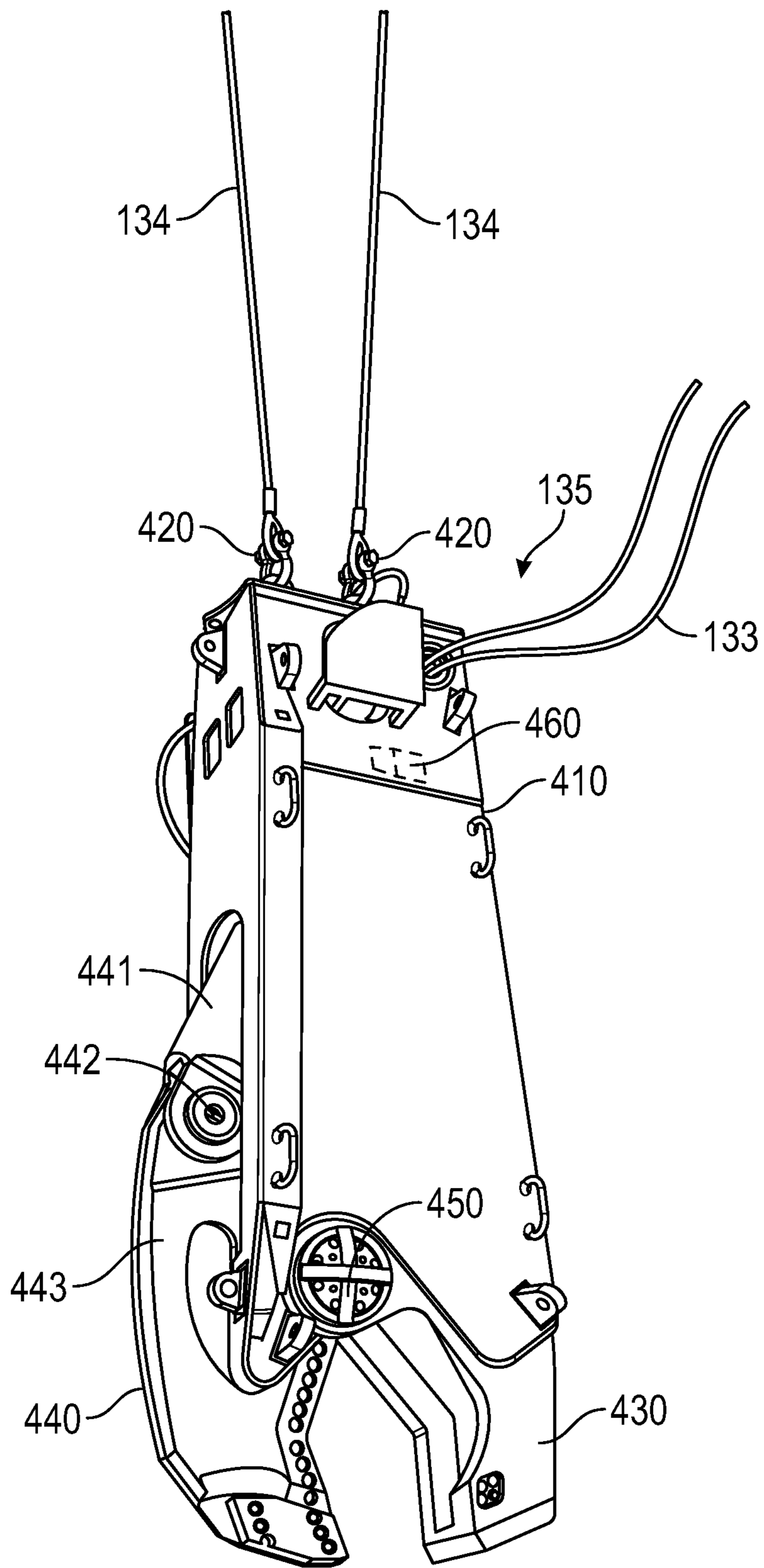


FIG. 4

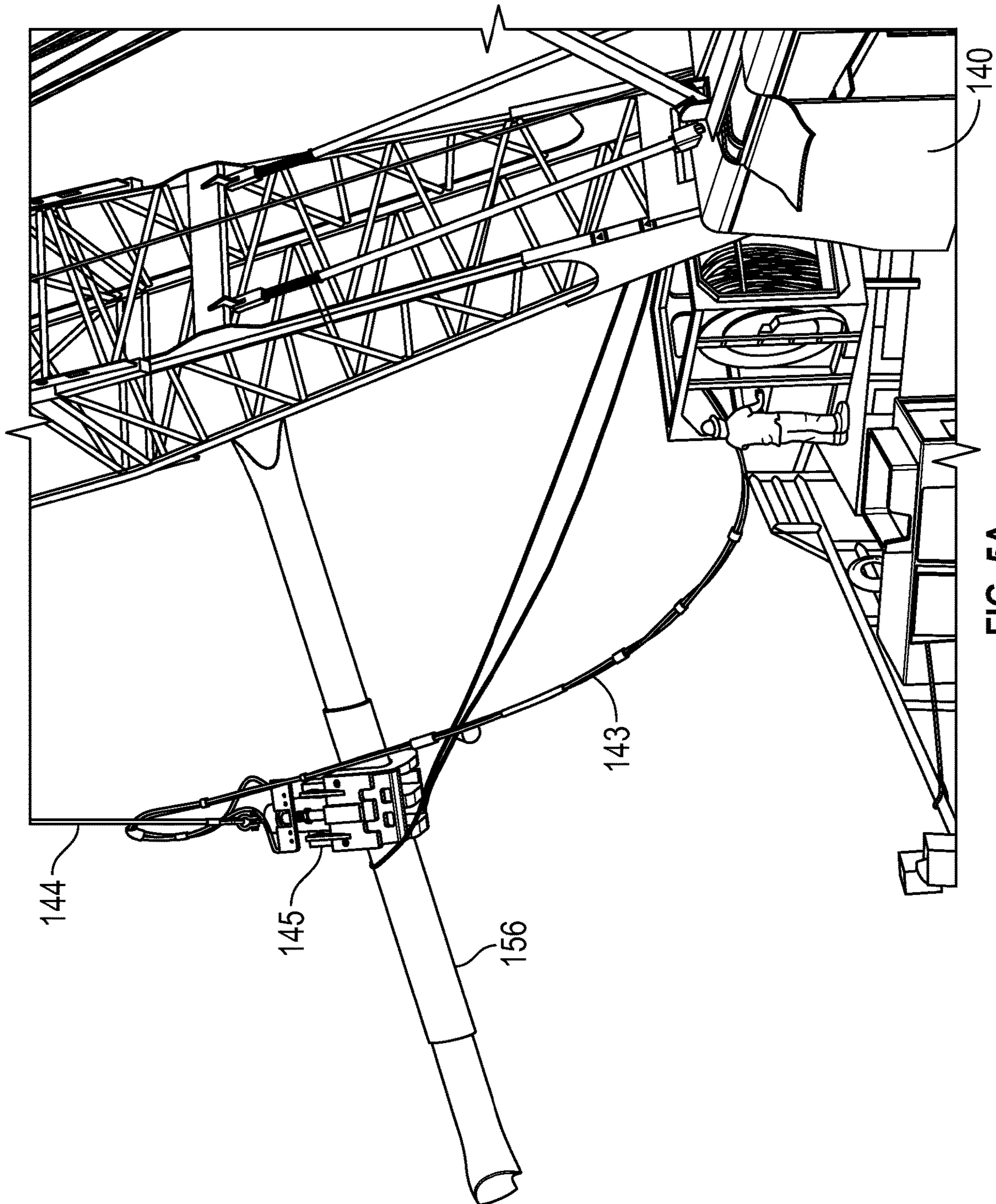


FIG. 5A

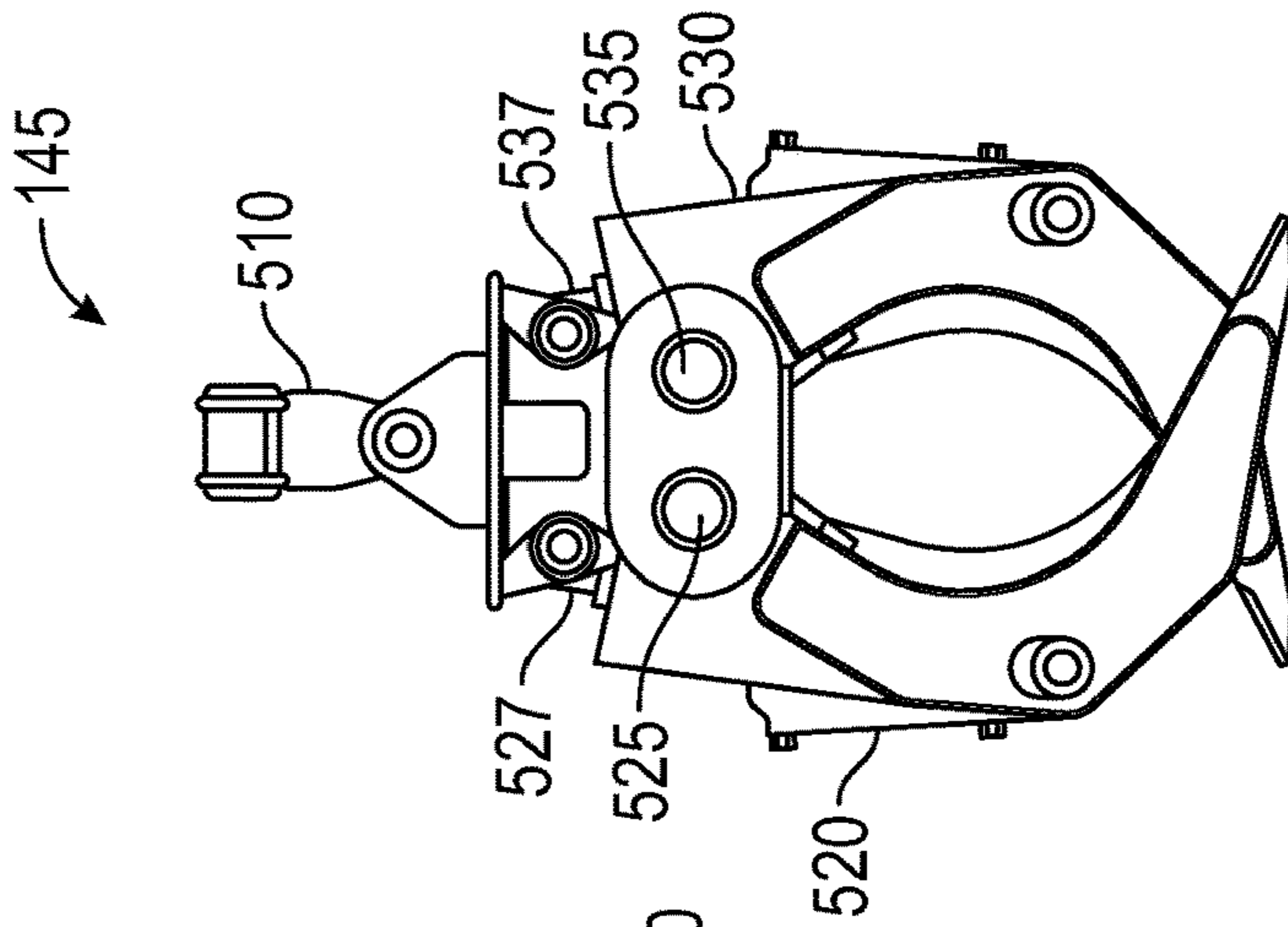


FIG. 5D

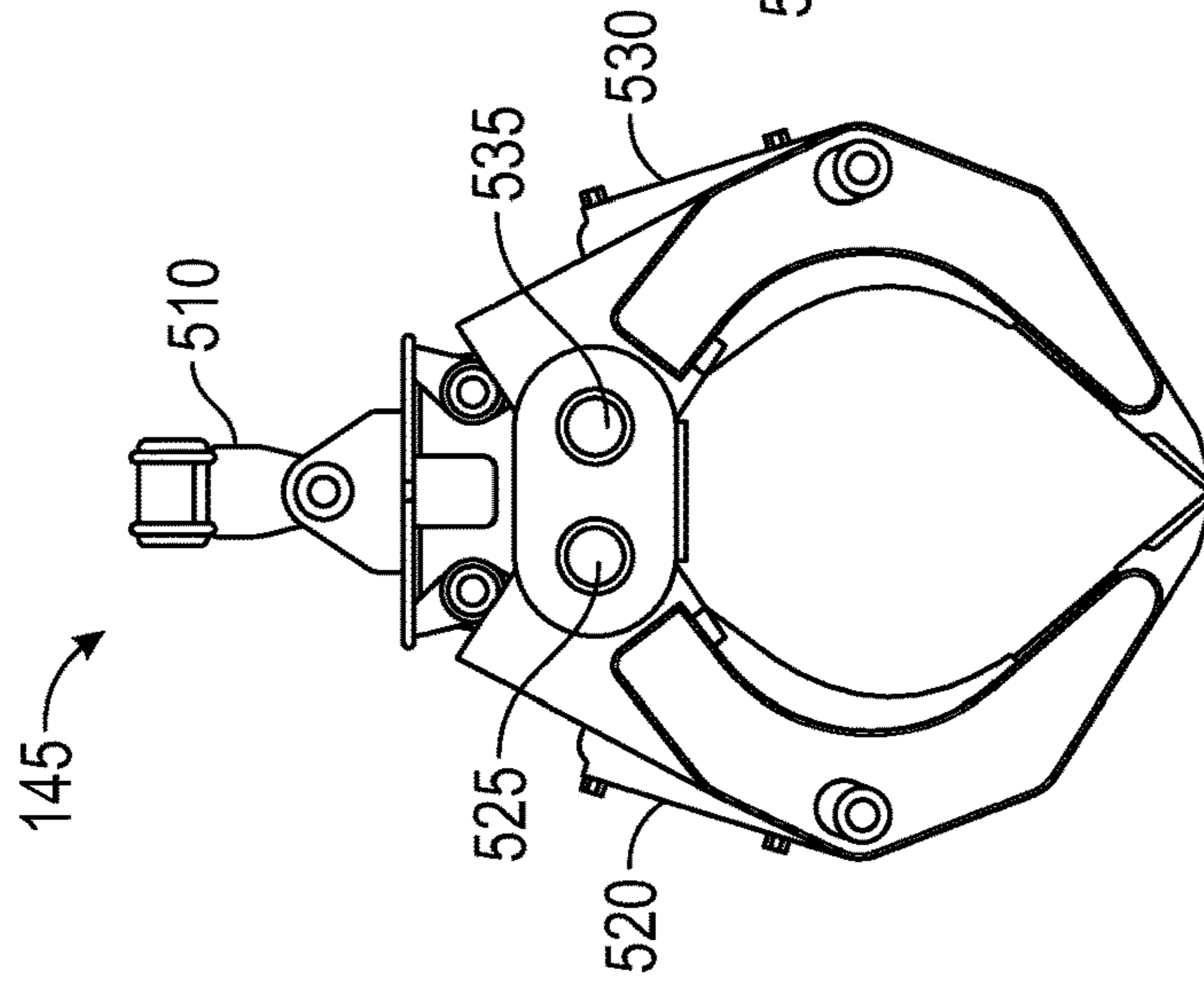


FIG. 5C

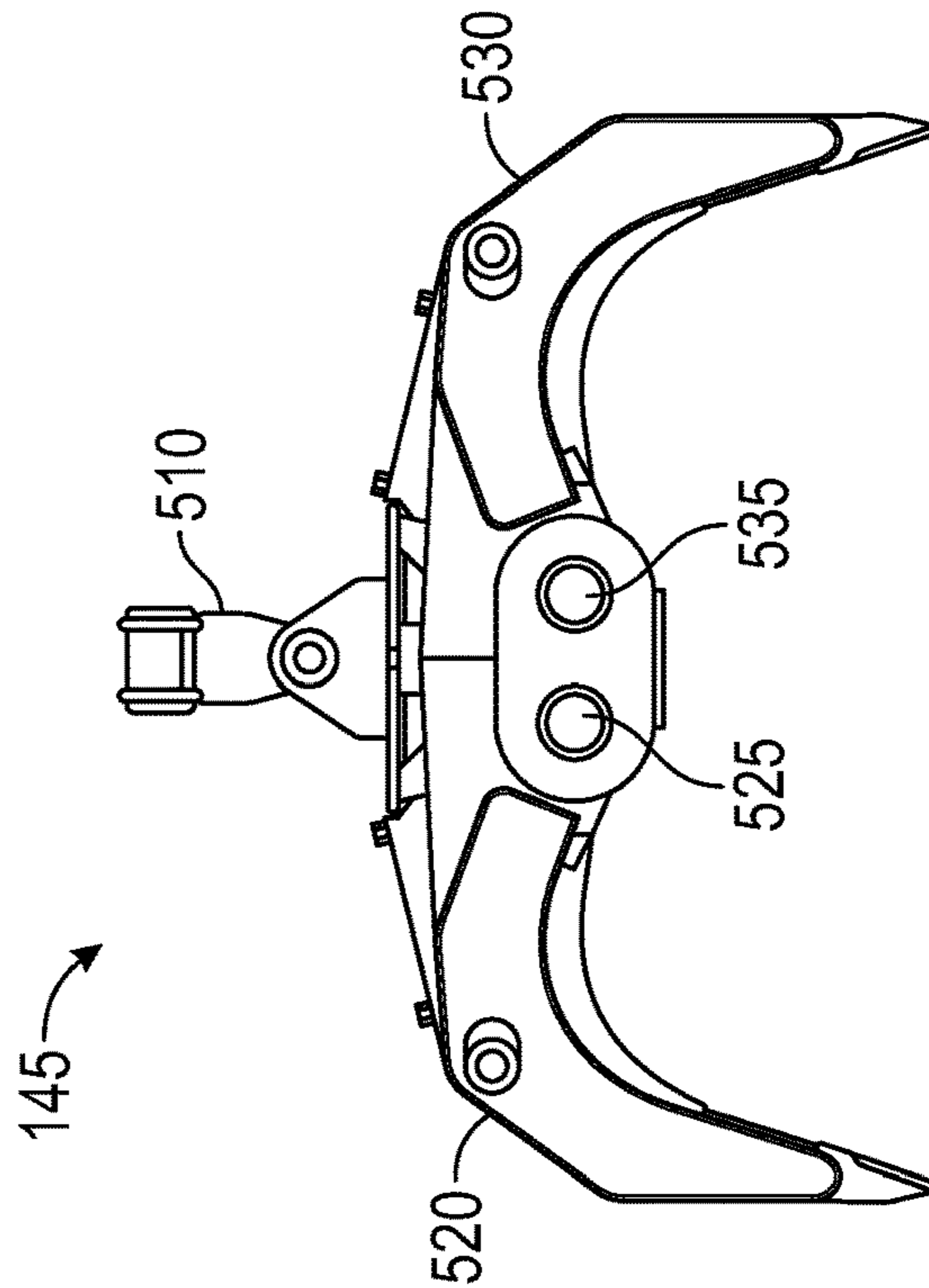


FIG. 5B

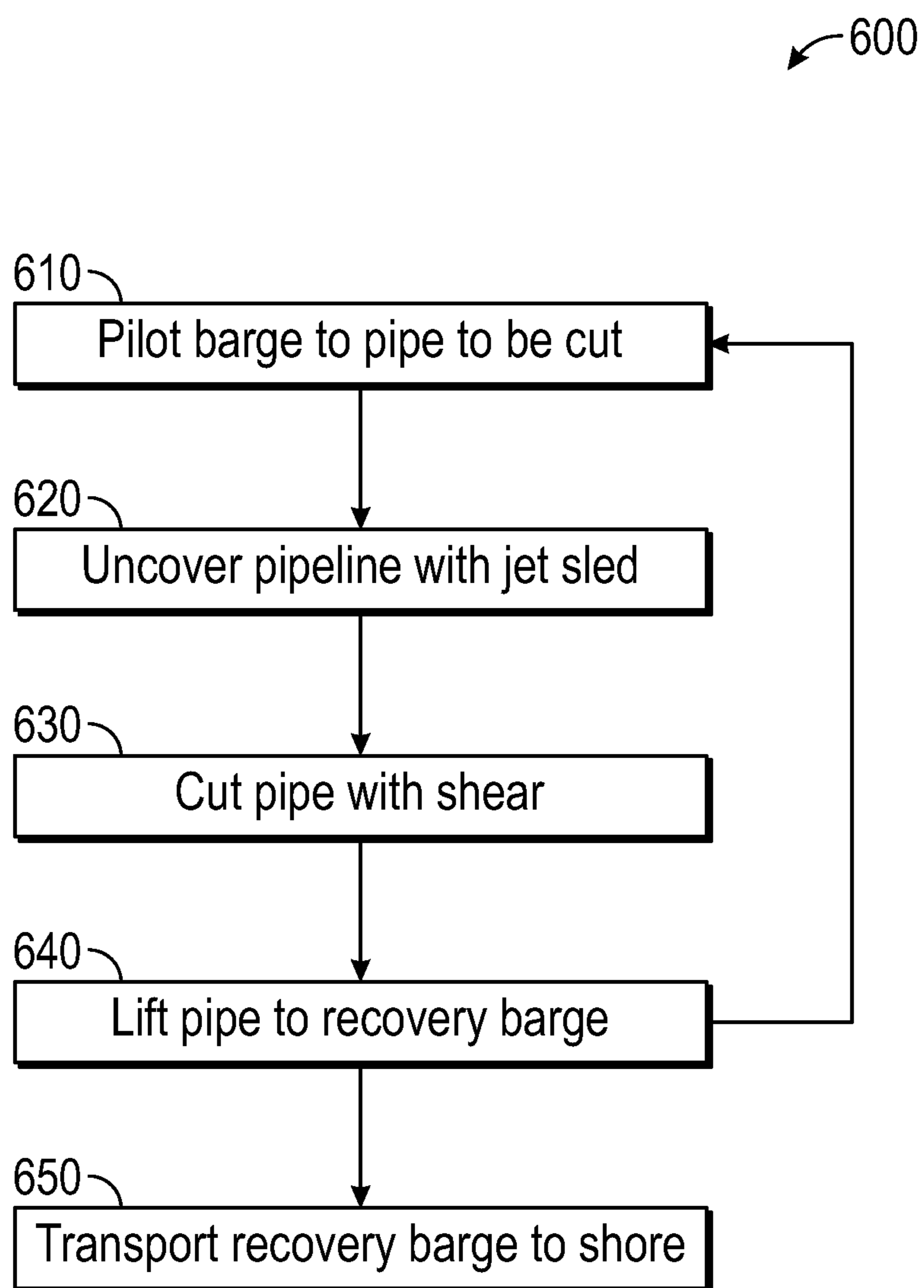


FIG. 6

SEAFLOOR PIPELINE REMOVAL SYSTEM AND METHOD

BACKGROUND OF THE INVENTION

I. Cross Reference to Related Applications

This application claims priority from U.S. Non-Provisional application Ser. No. 17/239,030 (Trahan et al.) filed Apr. 23, 2021, which is incorporated herein by reference as if set forth in full below.

II. Field of the Invention

The present invention relates generally to a system and method for removing a pipeline buried in the seafloor through the use of a pressurized trenching device for uncovering buried pipe, a hydraulic subsea pipe shear for cutting pipeline, and a hydraulic subsea grapple for lifting sections of cut pipe from the seafloor onto a barge.

III. General Background

Oil & gas extracted from below the seafloor (for example, in the Gulf of Mexico) are transported through pipelines which are buried below the seafloor. When a pipeline is no longer needed, the United States Government has traditionally required either: (1) that pipelines be removed from the seafloor, or (2) that pipelines be cleaned of oil & gas. Because larger pipelines can be cleaned and smaller pipelines cannot be cleaned, large pipelines are traditionally cleaned and left in place, while smaller pipelines are removed. Thus, for many years, the industry has learned to remove smaller pipelines from the seafloor. Traditionally, this involves lifting the pipe onto a barge, securing the pipe on the barge, and then cutting sections of pipe on the barge. However, lifting larger pipe onto a barge places too great of a strain on the sections of pipe between the barge and the seafloor. This strain could result in the pipeline breaking, thereby creating safety issues and also rendering the traditional solutions impossible or impractical. As a result, larger pipelines (i.e., the pipelines than can be cleaned) are cleaned rather than removed. However, recent regulations from the United States Government have started to require that larger pipelines be removed from certain areas. These regulations created a need for solutions to remove larger pipelines from the seafloor, such as the solutions disclosed herein.

Examples of subsea trenching devices used in the oil and gas industry in the Gulf of Mexico include those disclosed in U.S. Pat. No. 4,586,850 to Norman et al., U.S. Pat. No. 9,725,877 to Norman, and 10,066,362 to Ledet et al., all of which are incorporated by reference as if set forth in full below. While these types of subsea trenching devices have been used in offshore oil and gas environments for many years, we are only aware of such subsea trenching devices being used for pipeline installation below the seafloor, and we are not aware of such subsea trenching devices being used for pipeline removal. Thus, the disclosed trenching device includes improvements allowing use for uncovering already buried pipe.

Additional examples of subsea trenching devices include mass flow excavators, which push large flows of water (for example by using impellers) at the seafloor for the purpose of displacing the seafloor. One example of a mass flow excavator is disclosed in U.S. Pat. No. 8,893,408 to Susman et al., which is incorporated by reference as if set forth in full below. We speculate that mass flow excavators are designed

to be tethered from a vessel by means of a crane wire, which is used to lower and retrieve the excavator, and to maintain a given distance from the seafloor. We speculate that mass flow excavators are not suitable for use with the disclosed system and method because their operation requires additional equipment (e.g., another boat), thus resulting in seafloor falling back into a generated trench before shearing and lifting pipe can occur.

We speculate that, at the very least, the self-propelled nature of the jet sled, the position of the spray pipes and nozzles, the position of the air lifts, and the use of rollers described below allow for improved ability to unearth buried pipe. Moreover, the disclosed invention allows pipe to be unearthed, cut, and lifted onto a recovery barge in a “one pass” operation, thereby reducing the need for additional boats and barges and thereby improving the efficiency of pipeline removal methods.

SUMMARY OF THE INVENTION

In accordance with an embodiment, the present invention includes a pipeline removal system for removing pipeline from a seafloor, comprising a barge, a subsea trenching device, a trenching device controller, a subsea shear, a shear controller, a grapple, a grapple controller, and a pipe recovery barge, wherein said trenching device controller, said shear controller, and said grapple controller are positioned on a surface of said barge; wherein said subsea shear is connected to said shear controller and said shear controller is capable of controlling position and shear-action of said subsea shear, wherein said grapple is connected to said grapple controller and said grapple controller is capable of controlling position and grapple action of said grapple; wherein said subsea trenching device is connected to said trenching device controller and said trenching device controller is capable of controlling said subsea trenching device; wherein said subsea trenching device comprises a plurality of spray pipes and each of said plurality of spray pipes further comprises a plurality of nozzles, further wherein said trenching device controller is capable of delivering pressurized water to said subsea trenching device by a pressurized water hose, and said subsea trenching device is configured to spray said pressurized water out of said plurality of nozzles, thereby excavating a trench around a length of pipe buried below a seafloor and exposing an uncovered portion of said pipeline; wherein said subsea shear is capable of cutting said uncovered portion of said pipe, thereby creating a cut pipe section; wherein said grapple is capable of lifting said cut pipe section and placing said cut pipe section on said pipe recovery barge; wherein said pipe recovery barge is capable of hauling a plurality of cut pipe sections; wherein said subsea trenching device further comprises a plurality of air lift columns, each air lift column comprising an opening, an outlet, an interior space, and an air inlet, wherein said air inlet is located below said outlet, further wherein said trenching device controller is capable of delivering pressurized air to said subsea trenching device by a pressurized air hose, and each of said air lift column is configured to accept said pressurized air through each respective said air inlet, further wherein each of said plurality of air lift columns is capable of lifting water and particulate matter from a seafloor into each respective said opening, through each respective said interior space, and out of each respective said outlet as a result of said pressurized air flowing through each respective said interior space; wherein said subsea trenching device further comprises a plurality of rollers, wherein said subsea trenching device is capable of repositioning at least

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some of said plurality of rollers about a pipe to secure said subsea trenching device to said pipe; wherein said subsea trenching device is capable of causing a rolling action of at least some of said plurality of rollers and said subsea trenching device is capable of moving along said pipe as a result of said rolling action.

In accordance with an embodiment, the present invention includes a method of performing subsea pipeline removal comprising; (a) providing a barge, a subsea trenching device, a trenching device controller, a subsea shear, a shear controller, a grapple, a grapple controller, and a pipe recovery barge to an offshore location; (b) lowering said subsea trenching device into seawater and onto a pipe; (c) moving said subsea trenching device along a length of said pipe; (d) displacing seafloor using said subsea trenching device to unearth an uncovered portion of said pipe; (e) shearing said uncovered portion of said pipe with said subsea shear, thereby creating a cut portion of pipe; (f) lifting said cut portion of pipe with said grapple and placing said cut portion on said pipe recovery barge; wherein said trenching device controller, said shear controller, and said grapple controller are positioned on a surface of said barge; wherein said subsea shear is connected to said shear controller and said shear controller is capable of controlling position and shear-action of said subsea shear; wherein said grapple is connected to said grapple controller and said grapple controller is capable of controlling position and grapple action of said grapple; wherein said subsea trenching device is connected to said trenching device controller and said trenching device controller is capable of controlling said subsea trenching device; wherein said subsea trenching device is capable of excavating a trench around a length of said pipe buried below a seafloor, thereby exposing an uncovered portion of said pipe; wherein said subsea shear is capable of cutting said uncovered portion of said pipe, thereby creating a cut pipe section; wherein said grapple is capable of lifting said cut pipe section and placing said cut pipe section on said pipe recovery barge; wherein said pipe recovery barge is capable of hauling a plurality of cut pipe sections; wherein said subsea trenching device further comprises a plurality of spray pipes and each of said plurality of spray pipes further comprises a plurality of nozzles, wherein said displacing step comprises the steps of: delivering pressurized water from said subsea trenching device controller to said subsea trenching device; and spraying pressurized water out of said plurality of nozzles at said seafloor; wherein said subsea trenching device further comprises a plurality of air lift columns, each air lift column comprising an opening, an outlet, an interior space, and an air inlet, wherein said air inlet is located below said outlet, wherein said displacing step comprises the steps of: delivering pressurized air from said subsea trenching device controller to said subsea trenching device; injecting said pressurized air into said interior space of each said air lift column; creating a flow of said seawater through each said air lift column; and lifting a portion of said seafloor with said flow of said seawater; wherein said subsea trenching device further comprises a plurality of rollers, wherein lowering step comprises the step of moving at least some of said plurality of rollers closer to said pipe to secure said subsea trenching device to said pipe, further wherein said moving step is performed by rolling at least some of said plurality of rollers to propel said subsea trenching device along said pipe; wherein said subsea trenching device comprises at least one buoyancy tank, wherein said method further comprises the step of adjusting buoyancy of said subsea trenching device by injecting air into said at least one buoyancy tank and expelling air out of

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said at least one buoyancy tank; wherein said barge further comprises at least one sonar device for imaging said seafloor and providing visual indicators, wherein said shearing step comprises the step of identifying said seafloor and said pipe with said at least one sonar device to direct said subsea shear to said pipe, and wherein said lifting step comprises the step of identifying said seafloor and said cut portion of pipe with said at least one sonar device to direct said grapple to said cut portion of pipe.

In accordance with an embodiment, the present invention includes a subsea trenching device comprising a frame; a plurality of rollers connected to a bottom side of said frame, wherein said plurality of rollers are configured to secure said subsea trenching device to a pipe by moving at least some of said plurality of rollers closer to said pipe, further wherein at least some of said plurality of rollers are configured to roll in response to hydraulic control; a manifold connected to said frame for receiving pressurized water; a plurality of spray pipes connected to said frame and fluidly connected to said manifold, wherein each of said plurality of spray pipes further comprises a plurality of nozzles, further wherein at least one of said plurality of spray pipes is located on a first side of said plurality of rollers and at least one of said plurality of spray pipes is located on a second side of said plurality of rollers, further wherein said plurality of spray pipes extend approximately to a bottom of said pipe; wherein said plurality of nozzles are located on a length of each of said plurality of spray pipes, wherein said length extends approximately to said bottom of said pipe; wherein said subsea trenching device further comprises a plurality of air lift columns, wherein each air lift column is affixed to said frame; wherein each air lift column comprises an opening, an outlet, an interior space, and an air inlet, wherein said air inlet is located below said outlet; wherein each said opening is at about the same level as said bottom of said pipe; wherein at least one of said plurality of air lift columns is located on said first side and at least one of said plurality of air lift columns is located on said second side; wherein said trenching device is capable of receiving pressurized air through a pressurized air hose, and each of said air lift column is configured to accept said pressurized air through each respective said air inlet, further wherein each of said plurality of air lift columns is configured to lift water and particulate matter from a seafloor through each respective said interior space as a result of said pressurized air flowing through each respective said interior space; wherein said plurality of nozzles are configured to create a spray in an arc that extends approximately 90 degrees, from approximately parallel with said pipe to approximately perpendicular to and towards said pipe; wherein at least two of said plurality of air lift columns are located on said first side and at least two of said plurality of air lift columns is located on said second side, and wherein each said outlet of each air lift column is configured to direct said water and said particulate matter flowing through each said air lift column vertically and horizontally away from said subsea trenching device.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which like parts are given like reference numerals and, wherein:

FIG. 1 is a side view of a system for removing pipe from the seafloor.

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FIG. 2 is a top view of a system for removing pipe from the seafloor.

FIG. 3A is a perspective view of a jet sled.

FIG. 3B is a side view of a jet sled.

FIG. 3C is an opposite side view of a jet sled.

FIG. 3D is a front view of a jet sled.

FIG. 3E is a rear view of a jet sled.

FIG. 3F shows a detail view of a jet sled digging a trench to uncover a pipeline.

FIG. 3G is a cross-section view of a trench dug by a jet sled.

FIG. 4 is a perspective view of a subsea shear.

FIG. 5A is a perspective view of a grapple in use.

FIGS. 5B, 5C, and 5D are side views showing the movement of a grapple.

FIG. 6 is a block diagram showing a method of removing pipe from the seafloor.

DETAILED DESCRIPTION

FIG. 1 discloses a side view of a pipeline removal system 100 and shows barge 110, jet sled controller 120, jet sled hydraulic cable 121, jet sled pressurized air hose 122, jet sled lift cable 123 (not shown in FIG. 1, but shown in FIG. 2), jet sled pressurized water hose 124, jet sled 25 shear controller 130, shear hydraulic cable 133, shear lift cable 134, subsea shear 135, shear sonar device 136, grapple controller 140, grapple hydraulic cable 143, grapple lift cable 144, grapple 145, grapple sonar device 146, pipe 150, uncovered pipe section 151, cut pipe sections 152, 153, 154, and 155, and lifted pipe section 156. FIG. 1 also shows water 160 and seafloor 170.

In an exemplary embodiment, barge 110 is a pipe lay and recovery barge that is approximately 260 feet long by 72 feet wide and has a hull depth of 16 feet and an operating draft of 7 feet. In this exemplary embodiment, barge 110 has quarters to house 88 people, 2 decompression chambers, 3×445 kilowatt generators, and 2×232 cfm air compressors at 125 psi. In this exemplary embodiment, barge 110 also houses (for powering jet sled 125) two (2) Bingham 6×10 2-stage pumps and two (2) Caterpillar V12, 1175 HP 2800 GPM at 500 psi water pumps, and two (2) 900 CFM air compressors. Movement of barge 110 may be performed by a tugboat (not shown).

In an exemplary embodiment, jet sled 125 is a device capable of sitting on or above the seafloor and using pressurized air and/or water to remove sand or earth from the seafloor to create a trench. As used with the disclosed invention, jet sled 125 removes sand from the seafloor around pipe 150 to reveal uncovered pipe section 151. A jet sled 125 is a one example of a subsea trenching device.

In an exemplary embodiment, a jet sled controller 120 is provided for human control of jet sled 125. Jet sled 125 is connected to jet sled controller 120 by jet sled hydraulic cable 121, jet sled pressurized air hose 122, jet sled lift cable 123, and jet sled pressurized water hose 124. Jet sled hydraulic cable 121 is one or more hydraulic control cables capable of allowing jet sled controller 120 to hydraulically control jet sled 125. Jet sled pressurized air hose 122 is a hose capable of delivering pressurized air from jet sled controller 120 to jet sled 125. Jet sled pressurized water hose 124 is a hose capable of delivering pressurized water from jet sled controller 120 to jet sled 125. Jet sled 125 may be lowered into, or raised out of, water 160 by jet sled lift cable 123 by a crane on barge 110, and in some embodiments said crane may be shear controller 130. Some embodiments may include a plurality of jet sled hydraulic cables 121, and/or a

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plurality of jet sled pressurized air hoses 122 and/or a plurality of jet sled pressurized water hoses 124.

In this embodiment, water is pressurized in jet sled controller 120 and is pumped through jet sled pressurized water hose 124 to jet sled 125, and air is pressurized in jet sled controller 120 and is pumped through jet sled pressurized air hose 122, where the pressurized air or water exits through nozzles (not depicted in FIG. 1), causing sand or earth to be displaced from the seafloor around pipe 150.

In some embodiments, jet sled controller is a location within barge 110 containing equipment for pumping hydraulic fluid through jet sled hydraulic cable 121, air through jet sled pressurized air hose 122, and water through jet sled pressurized water hose 124. In some exemplary embodiments, such capabilities are provided by two (2) Bingham 6×10 2-stage pumps and two (2) Caterpillar V12, 1175 HP 2800 GPM at 500 psi water pumps, and two (2) 900 CFM air compressors. Any suitable device may be used to provide hydraulic control, pressurized air, or pressurized water from jet sled controller 120 on barge 110 to jet sled 125.

Additionally, jet sled 125 is controlled by human interaction with jet sled controller 120. Thus, a human can interact with jet sled controller 120, causing hydraulic fluid to flow through jet sled hydraulic cable 121 to move jet sled 125 (e.g., movement backwards or forwards along pipe 150 to uncover successive sections of pipe 150) and to start or stop the flow of pressurized water or air from jet sled 125.

In an exemplary embodiment, shear controller 130 is one or more devices configured to collectively control the position of subsea shear 135 through the length and position of shear lift cable 134 and configured to control the shear-action of subsea shear 135 by shear hydraulic cable 133. In an exemplary embodiment, shear controller 130 is the combination of a crawler crane configured to control the position of subsea shear 135 through shear lift cable 134 as well as a hydraulic control device for controlling the shear-action of subsea shear 135 through shear hydraulic cable 133. However, shear controller 130 may be a single crane capable of providing both lift and hydraulic control. In this exemplary embodiment, shear controller 130 includes a crawler crane powered by a diesel engine with 24-foot crawlers, 48-inch treads, and a counterweight system (which may be provided by a Manitowoc 4000-W crane), subsea shear 135 is a 20-ton hydraulic shear capable of cutting 30 inch pipe at a maximum depth of 7800 feet (which may be provided by a LaBounty brand hydraulic shear), shear hydraulic cable 133 is one or more cables that provide hydraulic control (e.g., containing pressurized hydraulic fluid), and shear lift cable 134 is one or more cables that lift subsea shear (e.g., stranded wire rope or other suitable cable). In other embodiments, other forms of lift and/or control may be used (e.g., electronic control), and other forms of providing shearing capabilities may be used.

In an exemplary embodiment, grapple controller 140 is one or more devices configured to collectively control the position of grapple 145 by grapple lift cable 144 and configured to control the grapple-action of grapple 145 by grapple hydraulic cable 143. In an exemplary embodiment, grapple controller 140 is the combination of a crawler crane configured to control the position of grapple 145 through grapple lift cable 144 as well as a hydraulic control device for controlling the grapple-action of grapple 145 through grapple hydraulic cable 143. However, grapple controller 140 may be a single crane capable of providing both lift and hydraulic control. In this exemplary embodiment, grapple controller 140 includes a crawler crane powered by a diesel engine with 24-foot crawlers, 48-inch treads, and a coun-

terweight system (which may be provided by a Manitowoc 4000-W crane), grapple **145** is a hydraulic grapple that weighs 8,000 pounds and which is capable of lifting up to 30,000 pounds and capable of grappling at least up to 24 inch outer diameter pipe, grapple hydraulic cable **143** is one or more cables that provide hydraulic control (e.g., containing pressurized hydraulic fluid), and grapple lift cable **144** is one or more cables that and lift grapple **145** (e.g., stranded wire rope of other suitable cable). In other embodiments, other forms of lift and/or control may be used (e.g., electronic control), and other forms of holding pipe **150** may also be used.

Shear sonar device **136** and grapple sonar device **146** are sonar devices that are capable of using sonar to provide images of the seafloor, and, more particularly, to provide images aiding in the positioning of subsea shear **135** and grapple **145** relative to uncovered pipe section **151** and cut pipe sections **152**, **153**, **154**, and **155**. Any suitable sonar may be used, and such devices are known to a person of skill in the art.

In some embodiments, an operator of shear sonar device **136** provides audible commands to one or more operators of shear controller **130** to direct the position of subsea shear **135** relative to uncovered pipe section **151** and to direct the shear-action of subsea shear **135** to shear uncovered pipe section **151**.

In some embodiments, an operator of grapple sonar device **146** provides audible commands to one or more operators of grapple controller **140** to direct the position of grapple **145** relative to one of the cut pipe sections **152**, **153**, **154**, or **155** and to direct the grapple-action of grapple **145** to cause grapple **145** to grasp one of the cut pipe sections **152**, **153**, **154**, or **155**.

The use of sonar devices reduces the need for divers to assist in the disclosed methods.

In an exemplary embodiment, water **160** is the Gulf of Mexico and the seafloor **170** is the outer continental shelf. However, the disclosed invention is not limited to use on the outer continental shelf in the Gulf of Mexico.

In exemplary embodiments, pipe **150** is a 20-inch diameter or 24-inch diameter pipeline used to transport oil or gas from a production well to shore. The disclosed invention may be used for other sizes of pipe **150**.

As a person of ordinary skill understands from FIG. 1, as barge **110** is piloted along the length of pipe **150**, jet sled controller **120** is used to pilot jet sled **125** along pipe **150** and to uncover the seafloor **170**, thereby revealing uncovered pipe section **151**. In an exemplary embodiment, jet sled **125** is piloted approximately 100 feet off the stern of barge **110**. Then, shear controller **130** is used to cause subsea shear **135** to cut uncovered pipe section **151**. This process is repeated along the length of pipe **150**, thereby creating one or more pipe sections that are cut and unearthed and ready for removal from the seafloor. In the embodiment depicted in FIG. 1, cut pipe sections **152**, **153**, **154**, and **155** are shown. However, the figure is not to scale, and the invention is not limited by the number of cut pipe sections on the seafloor underneath barge **110**. When barge **110** moves sufficiently along the length of pipe **150**, grapple controller **140** is used to cause grapple **145** to lift a lifted pipe section **156** off of the seafloor, which is then placed on pipe recovery barge **180** (not shown in FIG. 1). In this fashion, pipeline removal system **100** can be used to remove the length of pipe **150** from the seafloor **170**.

In an exemplary embodiment, cut pipe sections **152**, **153**, **154**, and **155** are cut to approximately 40 feet in length. However, other suitable cut pipe lengths can be used.

We speculate that this method can remove from seafloor **170**, and place on pipe recovery barge **180**, approximately 60 feet of pipe **150** per hour.

FIG. 2 depicts a plan view of pipeline removal system **100** and shows the same elements as FIG. 1, except that FIG. 2 depicts pipe recovery barge **180** carrying a plurality of recovered pipes **190**.

In an exemplary embodiment, pipe recovery barge **180** is a 180'x54' barge, although any suitable barge may be used. Movement of pipe recovery barge **180** may be performed by a tugboat (not shown). In some embodiments, multiple pipe recovery barges **180** are used. In one exemplary embodiment, each pipe recovery barge is capable of holding approximately 216 joints of 24-inch pipe having a load weight of 1,526 tons (5' freeboard).

FIG. 2 also shows jet sled **125** connected to shear controller **130** by jet sled lift cable **123**. Shear controller **130** may lift jet sled **125** into and out of water **160** using shear lift cable **134**. Subsea shear **135** may be disconnected from shear controller **130** during these operations.

FIG. 2 also shows an exemplary embodiment of the relative placement of jet sled controller **120**, shear controller **130**, and grapple controller **140** on barge **110**. In this exemplary embodiment, barge **110** is capable of carrying jet sled controller **120**, shear controller **130**, and grapple controller **140**.

As shown in FIG. 2, shear controller **130** and grapple controller **140** are placed along the longitudinal axis of barge **110**, with shear controller **130** being placed towards the stern of barge **110** and grapple controller **140** being placed towards the bow of barge **110**. Shear controller **130** and grapple controller counterbalance.

FIG. 2 also shows the trench **165** dug by jet sled **125**.

FIGS. 3A, 3B, 3C, 3D, and 3E depict jet sled **125**. Jet sled **125** is a subsea trenching device capable of uncovering pipe **150**. As used herein, the term "subsea," in addition to its plain and ordinary meaning, means "submersible" and "capable of underwater operation." In an exemplary embodiment, jet sled **125** accomplishes the goal of uncovering pipe **150** by using pressurized water.

FIGS. 3A-3E show jet sled hydraulic cable **121**, jet sled pressurized water hose **124**, body **200**, manifold **201**, first diversion hose **202**, second diversion hose **203**, first spray pipe **205**, second spray pipe **206**, a plurality of nozzles **210**, front top roller **215**, rear top roller **216**, first side front roller **217**, first side rear roller **218**, second side front roller **219**, second side rear roller **220**, first buoyancy tank **231**, second buoyancy tank **232**, mount **240**, jet sled lift strap **245**, and spray **250**.

FIGS. 3A-3E also show first air lift **280**, second air lift **282**, third air lift **284**, and fourth air lift **286**. First air lift **280** includes first outlet **281** and first air injector **290**. Second air lift **282** includes second outlet **283** and second air injector **292**. Third air lift **284** includes third outlet **285** and third air injector **294**. Fourth air lift **286** includes fourth outlet **287** and fourth air injector **296**.

In an exemplary embodiment, body **200** is a metal frame capable of holding and/or connecting to other portions of jet sled **125**, to jet sled pressurized water hose **124**, and to jet sled hydraulic cable **121**. Manifold **201** is a metal pipe connected to body **200** that is capable of receiving and making a sealed connection with jet sled pressurized water hose **124**. First diversion hose **202** and second diversion hose **203** provide a pressurized and fluid connection between manifold **201** and first spray pipe **205** and second spray pipe **206**, respectively. Both first spray pipe **205** and second spray pipe **206** have a plurality of nozzles **210** allowing water to

flow into manifold **201** through jet sled pressurized water hose **124**, then through first diversion hose **202** and second diversion hose **203** into first spray pipe **205** and second spray pipe **206**, then out of the plurality of nozzles **210**. Water flowing out of nozzles **210** moves seafloor **170** away from pipe **150**.

First spray pipe **205** and second spray pipe **206** are vertically oriented, and the plurality of nozzles **210** are located from the bottom of first spray pipe **205** and second spray pipe **206**, along the length of first spray pipe **205** and second spray pipe **206** for a length of approximately 5-6 feet. We speculate that this length of nozzle **210** placement is appropriate for the expected depth of pipe **150**. However, the length of nozzle **210** placement may be increased if the pipe **150** is buried deeper (and a deeper trench **165** is required). Lengths of 3 feet, 4 feet, 5 feet, 6 feet, 7 feet, 8 feet, 9 feet, and 10 feet may be used, in addition to lengths between the stated lengths, or longer lengths. Similarly, one or more nozzles **210** may be plugged if necessary or appropriate. Additionally, the nozzles **210** are oriented around a portion of the circumference of first spray pipe **205** and second spray pipe **206** such that the spray **250** leaving nozzles **210** varies between approximately parallel with pipe **150** and approximately perpendicular with pipe **150** (thereby forming an angle of approximately 90 degrees from each), with the spray **250** generally directed forward along the uncovered length of pipe **150** and towards pipe **150**. One or more nozzles **210** at the bottom of first spray pipe **205** and second spray pipe **206** may direct spray **250** at an angle somewhat wider than parallel to pipe **150**, i.e., angled somewhat away from pipe **150**. We speculate that this outward angle is appropriate at the bottom of first spray pipe **205** and second spray pipe **206** to direct sand from the seafloor **170** away from the trench that jet sled **125** is creating.

In some embodiments, the length of placement of nozzles **210** is less than the depth of the trench **165**, with nozzles **210** being positioned from just under pipe **150** to a location above pipe **150**. In one embodiment, nozzles **210** may be placed along a length of about 5 feet for the creation of a trench that is about 8 feet deep. In such an embodiment, the trench **165** is dug from the bottom, and seafloor **170** above the length of placement of nozzles **210** falls into the trench **165** as it is dug. This placement of nozzles **210** across less than the entire depth of the desired trench **165** is more efficient and allows for the use of less pressurized water, decreasing fuel and other costs.

In an exemplary embodiment, nozzles **210** are removable and replaceable and have openings that are between $\frac{1}{16}$ " and $\frac{1}{8}$ ". However, other diameters may be used. Smaller diameter openings may be used when higher pressure of spray **250** is suitable (e.g., where seafloor **170** is stiff clay or mud or compacted shells) and larger diameter openings may be used when lower pressure of spray **250** is suitable (e.g., where seafloor **170** is mostly sand). Nozzles **210** may further comprise tungsten or other abrasive-resistant inserts to reduce abrasion on nozzles **210** caused by sediment in water **160**.

In an exemplary embodiment, jet sled **125** receives pressurized water into manifold **201** through jet sled pressurized water hose **124** (which water was pressurized in jet sled controller **120**), and outputs water through the plurality of nozzles **210** for the purpose of creating spray **250**. Varying amounts of water may be used as necessary to effect trenching. The flow of water out of the plurality of nozzles **210** may be controlled by jet sled controller **120**. Pressurized air or combinations of pressurized air and water may also be used.

In an exemplary embodiment, first air lift **280**, second air lift **282**, third air lift **284**, and fourth air lift **286** are generally hollow metal columns having an opening generally located towards the bottom of jet sled **125**, having an interior space, and having an outlet generally towards the top of jet sled **125**, and with the walls of each providing a generally non-permeable barrier between the interior space and water **160**, and with each allowing a pipe-like flow of water through the interior space. Jet sled **125** receives pressurized air from jet sled pressurized air hose **122** (which air was pressurized in jet sled controller **120**) and outputs pressurized air from first air injector **290** into a lower portion of first air lift **280**, from second air injector **292** into a lower portion of second air lift **282**, from third air injector **294** into a lower portion of third air lift **284**, and from fourth air injector **296** into a lower portion of fourth air lift **286**.

The buoyancy of air relative to water causes the movement of air upwards through first air lift **280** and out of first outlet **281**, through second air lift **282** and out of second outlet **283**, through third air lift **284** and out of third outlet **285**, and through fourth air lift **286** and out of fourth outlet **287**. This movement of air also causes the upward movement of water **160** through first air lift **280**, second air lift **282**, third air lift **284**, and fourth air lift **286**. This upward movement of water causes a suction effect, thereby sucking both water **160** and matter such as sand or other particulate from seafloor **170** through first air lift **280** and out of first outlet **281**, through second air lift **282** and out of second outlet **283**, through third air lift **284** and out of third outlet **285**, and through fourth air lift **286** and out of fourth outlet **287**.

The rate of airflow out of first air injector **290**, second air injector **292**, third air injector **294**, and fourth air injector **296** may be controlled by jet sled controller **120**. However, in some embodiments, such airflow rates may be controlled by valves on jet sled **125**.

First outlet **281**, second outlet **283**, third outlet **285**, and fourth outlet **287** are angled, respectively, relative to first air lift **280**, second air lift **282**, third air lift **284**, and fourth air lift **286**. As such, the flow of air, water, and matter from seafloor **170** is directed both up (i.e., vertically) and away (i.e., horizontally) from jet sled **125**. This process creates sediment output **255** above and away from jet sled **125**. Sediment output **255** is depicted in FIG. 1 and FIG. 3F.

In other words, jet sled **125** is capable of causing spray **250** to dislodge and displace material from seafloor **170** (i.e., breaking up seafloor **170** and moving some material out of the way), but jet sled **125** is also capable of lifting sediment off of the seafloor **170** (i.e., acting as a "vacuum cleaner" for sediment, whether such sediment is naturally part of seafloor **170** or has been created by spray **250**).

In an exemplary embodiment, jet sled **125** is raised into and lowered out of water **160** by jet sled lift cable **123** connected to jet sled lift strap **245** connected to body **200** by mount **240**. Jet sled lift cable **123** may be connected to shear controller **130** or by any suitable crane. When first being lowered onto the seafloor **170**, as jet sled **125** is engaged, jet sled **125** settles on top of pipe **150** such that front top roller **215** and rear top roller **216** are directly above pipe **150** and first side front roller **217**, first side rear roller **218**, second side front roller **219**, and second side rear roller **220** are adjacent to pipe **150**. Thus, front top roller **215**, rear top roller **216**, first side front roller **217**, and first side rear roller **218**, second side front roller **219**, and second side rear roller **220** are rollably engaged with pipe **150** such that jet sled **125** rolls along pipe **150**.

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In some embodiments, front top roller **215**, rear top roller **216**, first side front roller **217**, first side rear roller **218**, second side front roller **219**, and second side rear roller **220** are hydraulically powered to control the movement of jet sled **125** along pipe **150** in response to control from jet sled controller **120**.

In some embodiments, one or more of front top roller **215**, rear top roller **216**, first side front roller **217**, first side rear roller **218**, second side front roller **219**, and second side rear roller **220** are hydraulically powered to move towards and away from pipe **150** in response to control from jet sled controller **120**. Thus, in one exemplary embodiment, jet sled **125** can settle on top of pipe **150**, then first side front roller **217**, first side rear roller **218**, second side front roller **219**, and second side rear roller **220** can be controlled to move towards pipe **150**, thus engaging and securing jet sled **125** about pipe **150**. We observe that the movement of first side front roller **217**, first side rear roller **218**, second side front roller **219**, and second side rear roller **220** as discussed allows for jet sled **125** to be securely and rollably engaged with pipe **150**, for varying diameters of pipe **150**.

In an exemplary embodiment, the buoyancy of jet sled **125** is maintained by buoyancy tanks. FIGS. 3A-3E show such an exemplary embodiment, with first buoyancy tank **231** and second buoyancy tank **232** connected to the top of body **200** on opposite sides, and along the length of jet sled **125**.

In some exemplary embodiments, first buoyancy tank **231** and second buoyancy tank **232** are open-bottomed and contain valves, (a) for allowing pressurized air from jet sled pressurized air hose **122** into first buoyancy tank **231** and/or second buoyancy tank **232** (thereby increasing the buoyancy of jet sled **125**), and (b) for allowing air to escape from first buoyancy tank **231** and/or second buoyancy tank **232**. The flow of air into and out of first buoyancy tank **231** and second buoyancy tank **232** may be controlled independently.

In some exemplary embodiments, first buoyancy tank **231** and second buoyancy tank **232** each comprise a plurality of internal chambers, and the flow of air into and out of each such internal chamber can be controlled independently. In one such exemplary embodiment, first buoyancy tank **231** and second buoyancy tank **232** each comprise three internal chambers.

In some embodiments, the valves for controlling the air contents of first buoyancy tank **231** and second buoyancy tank **232** are located on jet sled **125** and may be operated by divers. However, other embodiments may allow for jet sled controller **120** to control the operation of such valves, allowing an operator on barge **110** to control the buoyancy of jet sled **125**.

The independent control of air into and out of first buoyancy tank **231** and second buoyancy tank **232**, as well as the plurality of internal chambers of each, allows for the adjustment of the pitch and roll of jet sled **125**.

In an exemplary embodiment, mount **240** is connected to body **200** and is used as a connection point to connect jet sled **125** to a crane (not depicted) for lowering jet sled **125** into, and raising jet sled out of, water **160**.

We speculate that the disclosed jet sled **125** is an improvement over other trenching devices. Other trenching devices that are not secured to pipe **150** may result in the trench being too deep. In other words, trenching device that is not in a relatively fixed position relative to a pipe may continue to dig into the seafloor deeper than the bottom of the pipe, as opposed to digging a trench to the correct depth and continuing movement along the pipe. We speculate that

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affixing the jet sled **125** to the pipe as disclosed results in jet sled **125** creating a trench **165** that has the correct depth.

Additionally, other trenching devices are pulled by a boat. This can result in a vertical force lifting pipe **150**, which may not be suitable where pipe **150** has already been cut (i.e., the vertical force may lift jet sled **125** and pipe **150**). Additionally, other trenching devices are pulled horizontally from the top of the trenching device. If such devices were secured to pipe **150** to prevent the trenching device from digging too deep, a moment arm would be created between pipe **150** and the location of the horizontal pull. This would result in torque being applied to pipe **150** by jet sled **125**. This torque is not suitable. Accordingly, we speculate that the self-propelled nature of jet sled **125** solves problems with using prior devices (which prior devices were designed for pipeline burial) for pipeline removal.

FIG. 3F shows a detail view of jet sled **125** digging a trench **165** around pipe **150** to uncover uncovered pipe section **151**.

FIG. 30 shows a cross sectional view of uncovered pipe section **151** in trench **165** dug by jet sled **125**.

FIG. 4 depicts an exemplary embodiment of subsea shear **135**. As discussed above, subsea shear **135** is a 20-ton hydraulic shear capable of cutting 30 inch pipe at a maximum depth of 7800 feet (which may be provided by a LaBounty brand hydraulic shear). Subsea shear **135** comprises shear body **410**, mounts **420**, shear-receiving-body **430**, shear-action assembly **440**, fixed joint **450**, and hydraulic assembly **460**. Shear-action assembly **440** further comprises extension member **441**, shear-action assembly joint **442**, and shear-action-member **443**.

Subsea shear **135** is capable of receiving one or more shear hydraulic cables **133**, which connect to hydraulic assembly **460**. Shear controller **130** is capable of controlling the shear-action of subsea shear **135** via hydraulic control through shear hydraulic cables **133**.

Subsea shear **135** has a top end for connecting to a lift device and a bottom end for performing a shear-action. Shear body **410** is a metal frame capable of holding or connecting to all of the components of subsea shear **135**. One or more mounts **420** are connected to shear body **410** on the top end of subsea shear **135**. Mounts **420** allow a removable connection to shear lift cable **134**.

The bottom end of subsea shear **135** comprises shear-receiving-body **430**, shear-action assembly **440**, and fixed joint **450**. The movement of shear action assembly about fixed joint **450** causes a shear-action. More specifically, hydraulic assembly **460** causes the extension of extension member **441**. Because extension member **441** is connected to shear-action-member **443** by shear-action assembly joint **442**, the extension of extension member **441** causes the rotation of shear-action-member **443** about fixed joint **450**, thereby causing the shear-edge of shear-action-member **443** to move closer towards shear-receiving-body **430**. As the shear-edge of shear-action-member **443** moves towards shear-receiving-body **430**, the force of the shear-action is capable of causing the shearing of uncovered pipe section **151**. In some embodiments, shear-receiving-body **430** is capable of receiving the shear-edge of shear-action-member **443** (i.e., shear-action-member **443** moves into a recess in shear-receiving-body **430**), further enhancing the ability of subsea shear **135** to shear uncovered pipe section **151**.

Other means for cutting uncovered pipe section **151** may be used.

FIG. 5A depicts a grapple **145** grappling and lifting a lifted pipe section **156** through the action of grapple hydro-

lic cable 143 and grapple lift cable 144. FIG. 5A also shows grapple controller 140 on barge 110.

FIGS. 5B, 5C, and 5D depict an exemplary embodiment of grapple 145 (and, collectively depict an exemplary embodiment of the grapple-action of grapple 145).

In this exemplary embodiment, grapple 145 comprises grapple mount 510, first grapple arm 520, first grapple joint 525, first grapple extension arm 527, second grapple arm 530, second grapple joint 535, and second grapple extension arm 537. Grapple hydraulic cable 143 (receiving control from grapple controller 140) causes the hydraulically-powered extension of first grapple extension arm 527 and second grapple extension arm 537. Because first grapple extension arm 527 and second grapple extension arm 537 are affixed to grapple 145, the extension of each causes first grapple arm 520 and second grapple arm 530 to each rotate about first grapple joint 525 and second grapple joint 535, respectively.

In this exemplary embodiment, grapple lift cable 144 may be connected to grapple mount 510, allowing grapple controller 140 to lift, lower, and position grapple 145.

Other means for lifting and moving lifted pipe section 156 may be used.

FIG. 6 depicts an exemplary embodiment of pipeline removal method 600, which is a method of using pipeline removal system 100, comprising piloting step 610, trenching step 620, shearing step 630, grappling step 640, and transporting step 650.

In this exemplary embodiment, first, piloting step 610 is performed. In piloting step 610, barge 110 is piloted to a location near an end of pipe 150 to be uncovered, jet sled 125 is lowered into water 160, and jet sled 125 is positioned directly above pipe 150. Then, rollers on jet sled 125 are engaged, causing said rollers to rollably affix and secure jet sled 125 to pipe 150, as discussed in more detail above. The method then proceeds to trenching step 620.

In this exemplary embodiment, in trenching step 620, jet sled 125 is controlled to cause water (in some embodiments, water 160) to flow through jet sled pressurized water hose 124, into manifold 201, then into first diversion hose 202 and second diversion hose 203, then into first spray pipe 205 and second spray pipe 206, and finally out of the plurality of nozzles 210, thereby creating spray 250. Spray 250 causes the formation of trench 165 in seafloor 170 and causes uncovered pipe section 151 of pipe 150 to be unearthed and revealed. If jet sled 125 has not already settled onto pipe 150, the formation of trench 165 causes the settling of jet sled 125 onto uncovered pipe section 151. In some exemplary embodiments, jet sled 125 is lowered onto a section of uncovered pipe section 151 created by manual digging of trench 165 by one or more divers (not shown) or by other subsea mechanical means.

Then, front top roller 215, rear top roller 216, first side front roller 217, first side rear roller 218, second side front roller 219, and second side rear roller 220 are rollably engaged with uncovered pipe section 151. Jet sled 125 is then propelled, by the motion of front top roller 215, rear top roller 216, first side front roller 217, first side rear roller 218, second side front roller 219, and second side rear roller 220, along uncovered pipe section 151, thereby causing spray 250 to lengthen trench 165, uncovering more pipe 150 and creating a longer uncovered pipe section 151. The method then proceeds to shearing step 630.

In shearing step 630, if a long enough length of uncovered pipe section 151 has been created, subsea shear 135 is used to cut uncovered pipe section 151, creating one or more cut pipe sections (shown in FIG. 1 as cut pipe sections 152-155). The method then proceeds to grappling step 640.

In grappling step 640, if shearing step 630 has created a length of cut pipe section that is accessible by grapple 145 (e.g., if jet sled 125 has progressed long enough along pipe 150 to allow grapple 145 to reach a cut pipe section), grapple 145 is used to lift a cut pipe section (shown in FIG. 1 as lifted pipe section 156). Grapple 145 is then used to place the cut and lifted pipe section onto pipe recovery barge 180 (shown in FIG. 2 as recovered pipes 190). The method then proceeds to piloting step 610 and transporting step 650.

In transporting step 650, pipe recovery barge 180 is piloted to a remote location for the removal of recovered pipes 190. Pipe recovery barge 180 then returns to barge 110. In some embodiments, multiple pipe recovery barges 180 are used, thereby avoiding the need to wait for the unloading and return of pipe recovery barge 180.

In some embodiments, the foregoing steps are performed in parallel.

The foregoing description of the embodiments of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the invention. The embodiments were chosen and described in order to explain the principles of the invention and its practical application to enable one skilled in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the allowed claims and their equivalents. The scope of the present invention should, therefore, be determined only by the following allowed claims.

What is claimed is:

1. A pipeline removal system for removing pipeline from a seafloor, comprising: a barge, a subsea trenching device, and a trenching device controller,

wherein said trenching device controller is positioned on a surface of said barge;

wherein said subsea trenching device is connected to said trenching device controller and said trenching device controller is capable of controlling said subsea trenching device;

wherein said subsea trenching device comprises a plurality of spray pipes and each of said plurality of spray pipes further comprises a plurality of nozzles, further wherein said trenching device controller is configured to deliver pressurized water to said subsea trenching device by a pressurized water hose, and said subsea trenching device is configured to spray said pressurized water out of said plurality of nozzles, thereby excavating a trench around a length of pipe buried below a seafloor and exposing an uncovered portion of said pipeline;

wherein said subsea trenching device comprises a plurality of rollers configured to secure said subsea trenching device to said pipe;

wherein said plurality of nozzles are located along a portion of each of said plurality of spray pipes;

wherein a bottom of said portion of each of said plurality of spray pipes is located at approximately a bottom of said plurality of rollers and a top of said portion of each of said plurality of spray pipes is located at approximately said seafloor.

2. A pipeline removal system for removing pipeline from a seafloor, comprising: a barge, a subsea trenching device, a trenching device controller, a subsea shear, a shear controller, a grapple, and a grapple controller,

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wherein said trenching device controller, said shear controller, and said grapple controller are positioned on a surface of said barge;

wherein said subsea shear is connected to said shear controller and said shear controller is capable of controlling position and shear-action of said subsea shear;

wherein said grapple is connected to said grapple controller and said grapple controller is capable of controlling position and grapple action of said grapple;

wherein said subsea trenching device is connected to said trenching device controller and said trenching device controller is capable of controlling said subsea trenching device;

wherein said subsea trenching device comprises a plurality of spray pipes and each of said plurality of spray pipes further comprises a plurality of nozzles, further wherein said trenching device controller is capable of delivering pressurized water to said subsea trenching device by a pressurized water hose, and said subsea trenching device is configured to spray said pressurized water out of said plurality of nozzles, thereby excavating a trench around a length of pipe buried below a seafloor and exposing an uncovered portion of said pipeline;

wherein said subsea shear is capable of cutting said uncovered portion of said pipe, thereby creating a cut pipe section;

wherein said grapple is capable of lifting said cut pipe section.

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3. A method of performing subsea pipeline removal comprising:

- a. providing a barge, a subsea trenching device, a trenching device controller, a subsea shear, a shear controller, a grapple, and a grapple controller to an offshore location;
- b. lowering said subsea trenching device into seawater and onto a pipe;
- c. moving said subsea trenching device along a length of said pipe;
- d. displacing seafloor using said subsea trenching device to unearth an uncovered portion of said pipe;
- e. shearing said uncovered portion of said pipe with said subsea shear, thereby creating a cut portion of pipe;
- f. lifting said cut portion of pipe with said grapple;

wherein said trenching device controller, said shear controller, and said grapple controller are positioned on a surface of said barge;

wherein said subsea shear is connected to said shear controller and said shear controller is capable of controlling position and shear-action of said subsea shear;

wherein said grapple is connected to said grapple controller and said grapple controller is capable of controlling position and grapple action of said grapple; and

wherein said subsea trenching device is connected to said trenching device controller and said trenching device controller is capable of controlling said subsea trenching device.

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